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RF Compatibility of VLBI with DORIS and SLR at GGOS Stations: an Experimental Methodology to Validate the Models

Christoper Beaudoin [1], *Brian Corey* [1], *Lawrence Hilliard* [2], *Bill Petrachenko* [3]

[1] *MIT Haystack Observatory*
[2] *NASA/GSFC*
[3] *Natural Resources Canada*

Contact author: Christoper Beaudoin, e-mail: cbeaudoin@haystack.mit.edu

Abstract

Previously, numerical analyses have been conducted in an attempt to quantify the power levels transmitted by the DORIS and SLR techniques that may be tolerated by the VLBI technique so as to avoid degradation of the VLBI observables. In this paper, we present the experimental methods that will be implemented to validate assumptions of the hardware performance in our numerical analyses.

1. Introduction

A continuing thrust in the space geodetic community is to deploy instruments using different techniques at common sites. While the close proximity (of order 100 meters) of the instruments to each other affords improved inter-comparison tests, it also increases the potential for interference between instruments. Of present concern to VLBI are DORIS beacons and the aircraft surveillance radars used in conjunction with satellite laser ranging (SLR). Initial numerical studies [1] were conducted to obtain rough estimates of the degree to which the VLBI SNR is degraded for various levels of DORIS and SLR radar interference. Numerical studies are only as good as the models upon which they are based, and there is sufficient uncertainty regarding their accuracy. For this reason, field and laboratory validation is planned to validate these a priori assumptions. The assumptions to be validated include the following:

- Radiation properties of transmitters in the GGOS,
- Sidelobe envelope of the 12-m VLBI antenna, and
- VLBI receiver frontend saturation.

The numerical studies [1] also raised concerns about the sky coverage loss that would be incurred by the VLBI technique in order to avoid degradation to the observables. Since sky coverage is paramount to the accuracy and precision of the geodetic VLBI solutions, barriers are being considered to ease the loss of sky coverage that would otherwise be lost to the VLBI technique.

2. Field Measurement of GGOS Transmitters at GGAO

2.1. Purpose

In order to quantify the power levels received at the VLBI antenna, the characteristics of the transmitting systems must be understood.

2.2. Results

Tables 1 and 2 demonstrate this level of understanding through comparison of measured and expected power levels. The measured power levels are those received through a standard gain horn antenna, the gain characteristics of which are well-understood. The expected power levels are computed from the Friis transmission formula and are based on the power transmitted by the particular antenna, the frequency, the gain of the transmit and receive antennas, and displacement between the two antennas.

Table 1. Field Measurements and expected DORIS power levels. Expected levels assume clear line-of-sight from DORIS to the field receiver.

Location	**Power**		**Distance**	**LOS**	
	Measured	**Calculated**		**Clear?**	**Blockage**
DORIS Pad	−1 dBm	−1.3 dBm	6.4 m	YES	0
Field	−43.7 dBm	−28.6 dBm	148.5 m	NO	15 dB
Observatory Pad	−27.6 dBm	−29.5 dBm	163.7 m	YES	0
MV3 Post	−44.3 dBm	−30.8 dBm	191.7 m	NO	13 dB

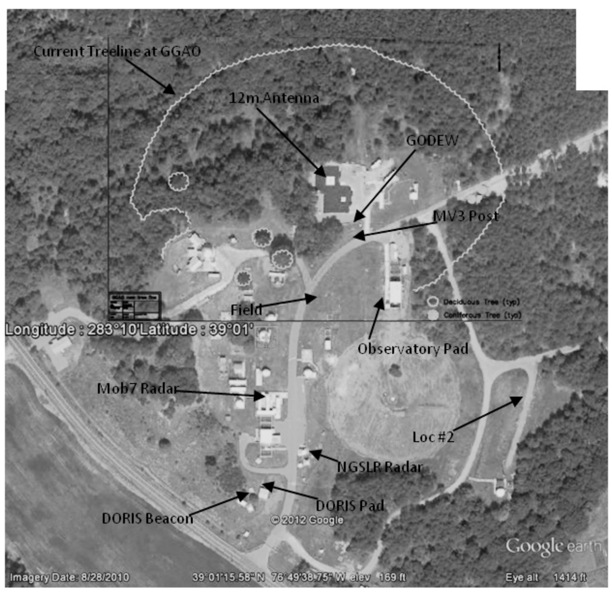

Figure 1. Map of GGAO identifying locations of DORIS and SLR-radar transmitters and locations at which power level measurements were collected.

3. Test of GGAO 12-m Sidelobe Model

3.1. Purpose

The sidelobe envelope presented in Figure 2 provides an empirically developed model, below which the 90th percentile of all the antenna sidelobe levels are expected to reside. The ITU-R

Table 2. Field measurements of SLR aircraft tracking radar power levels and corresponding expectations. Uncertainty in expectation is due to ambiguity in radar antenna pattern (see Reference 2). The results reported here are those from [2] for which the radars were stripped of their operational provisions (e.g. radome, fall-protection railings). These provisions influence the radar's transmitting characteristics as shown in [2].

	Mob7		NGSLR	
	Expectation	Measured	Expectation	Measured
GODEW	[−3.0 +1.0] dBm	−0.8 dBm	No Line-of-Sight	
Loc#2	[−6.1 −2.1] dBm	−4.9 dBm	[−4.9 −1.0] dBm	−3.6 dBm

model shown in Figure 2 is convenient for numerical analyses; however, given the complex nature of the scattering mechanisms associated with the antenna, it is difficult to assert that the ITU-R SA.509 sidelobe envelope model is applicable to the 12-m antenna. For this reason, experimental verification of the 12-m antenna's sidelobe envelope will be measured.

3.2. Planned Experimentation

To validate the sidelobe model, a separate field test of the 12-m sidelobe envelope is planned. The field test will be carried out with a mobile beacon transmitting at frequencies close to the DORIS and aircraft tracking radar frequencies, 2.036 and 9.4 GHz, respectively.

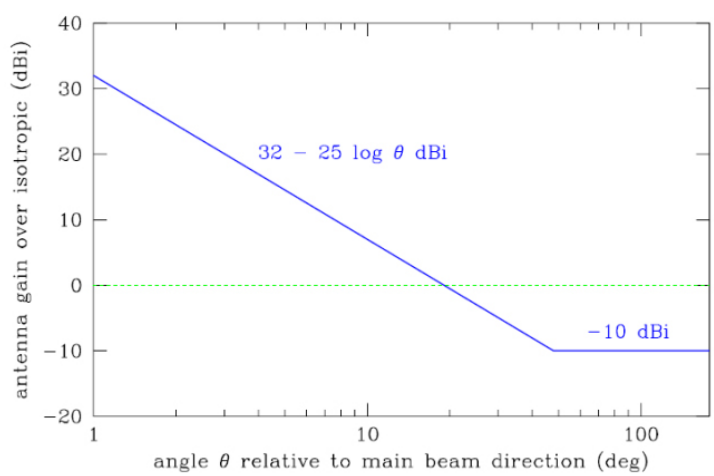

Figure 2. ITU-R SA.509 antenna sidelobe envelope model incorporated in numerical RFI-compatibility studies.

4. Receiver Saturation Characterization

4.1. Purpose

The degradation in the VLBI observable depends strongly on the noise and saturation performance of the LNA. For this reason, both the 1 dB compression point and OIP3 characteristics will be measured as a function of frequency. Given the coupling between an LNA's noise performance and its capacity to saturate, the variation of the CRYO1-12 LNA's noise performance will be studied under varied levels of saturation.

4.2. Planned Experimentation

The broadband VLBI receiver frontend is based on the Caltech LNA CRYO1-12. An Agilent N5222A will be used to measure the 1 dB compression point and two-tone intercept point of the CRYO1-12 LNA in order to quantify the broadband saturation characteristics of this LNA. An Agilent MXA N9020A signal analyzer with noise figure option will be used to characterize the room temperature noise figure of the LNA under varied levels of saturation. Measurements of the LNA noise figure at cryogenic temperature are not possible with the currently available hardware. However, the room temperature dependence of the noise figure on saturation level should provide adequate information to infer the degradation of the cryogenic noise figure based on the saturation levels.

Lastly, the expected degradation of the VLBI observable will be characterized in a controlled zero-baseline experiment whereby one station will be exposed to varied levels of S and X-band pseudo-RFI. In this test, the loss in amplitude of the zero-baseline correlation coefficient will be characterized under varied levels of saturation.

5. Barrier Efficacy

5.1. Purpose

Based on the numerical study [1], the VLBI sky coverage must be significantly restricted if the transmitting techniques are placed within 100 m of the VLBI antenna. For this reason, a comprehensive electromagnetics analysis of physical barriers/blockages has been undertaken to mitigate the offending signal levels and provide satisfactory VLBI sky coverage at GGOS stations. The barrier is expected to have little impact on the SLR radar performance. However, considerations in the barrier design are being made to ensure that a DORIS barrier does not introduce significant multipath which is a source of position error to the DORIS technique.

5.2. Planned Experimentation

Once the computational barrier analyses have been completed, they will be verified experimentally. The barriers are planned to be tested first with mock-transmitters. This will be minimally intrusive to DORIS/SLR operations and will provide sufficient flexibility to carefully study the results of these experiments. Assuming the results obtained using the mock-transmitters are satisfactory (i.e., barrier provides sufficient shielding), the respective barriers will be deployed to the SLR and DORIS techniques, where the testing process will be repeated. Upon successful installation of the DORIS barrier (as far as VLBI is concerned), the IDS will undergo a one-month trial observation with the new barrier to evaluate its impact on the DORIS observations.

6. Discussion and Conclusions

Preliminary power level specifications have been computed based on a numerical model [1] of the transmit/receive systems at GGOS stations. The experimental methodology presented here will be used to validate assumptions of the numerical model or be used to augment the aforementioned assumptions if they are grossly incorrect.

Comparison of field measurements and expectations regarding the DORIS and SLR-radar transmitters is outlined in Tables 1 and 2. The data reported in these tables show that the DORIS measurements are in agreement to within 2 dB of the expected power levels. The SLR radar results, when the radome/railings are removed from the radar, are also within 2 dB and nearly equidistant from either limit of sidelobe uncertainties in the expected results. Given this level of agreement, we conclude that the transmission properties of these systems are sufficiently well-understood for this RFI compatibility study. As shown in [2], these operational provisions do influence the transmitting characteristics of the radar. Since the Friis tranmission formula does not consider line-of-sight scattering effects, a more detailed model of the complete radiation pattern (i.e., radar/radome/railings) is needed to fully describe the transmission characteristics. This complete transmission characteristic should be well-understood to ensure that the radar power levels in the direction of the VLBI antenna are adequately mitigated.

Based on the numerical model [1], when placed 100 m from the VLBI antenna, the radar signal levels must be attenuated by a factor of 36 dB so as not to exceed 5° of VLBI sky loss coverage in the direction of the radar (assuming the radar never points within 10° of the VLBI antenna). In the case of DORIS, the required attenuation is 25 dB for the same VLBI sky loss specification. Metallic barriers are currently being considered as a means to provide the necessary attenuation and these results are forthcoming.

Computation of the required signal attenuation is critically dependent upon the sidelobe envelope of the VLBI antenna, which is currently assumed to conform to the ITU-R SA.509 specification. If the true sidelobe envelope of the 12-m antenna significantly exceeds this specification, then a redesign of the barrier may be necessary. Similarly, the required attenuation is dependent on the actual power levels that the LNA may tolerate before significant loss of signal-to-noise ratio in the VLBI observable. For this reason, it is also important to experimentally verify the LNA's broadband power handling capability.

Acknowledgements

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